

Demonstration of Rich Reagent Injection in Ameren's Sioux Unit 1

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SUMMARY

Previous research has shown that the injection of ammonia or urea into high temperature NO_x containing fuel rich flue gases from fossil fuel combustion can lead to noncatalytic NO_x reductions of 80% or better under idealized conditions. While SNCR involves the injection of amine reagents into fuel lean combustion products at temperatures between 1700 and 2100°F, reagent injection in the RRI process occurs at significantly higher gas temperatures under fuel rich conditions. With support from EPRI's Cyclone NO_x Control Interest Group (CNCIG) and NETL, REI and EPRI have evaluated the application of RRI to utility boilers through pilot scale testing, computational fluid dynamic (CFD) simulations, and field testing. During spring 2002, field testing of RRI was completed in Ameren's Sioux unit 1, a 500 MW cyclone fired boiler that was recently retrofit with overfire air (OFA). This was the second of two demonstrations of RRI, the first being in Conectiv's B.L. England Unit 1, a 130 MW single wall fired cyclone furnace. That testing demonstrated NO_x reductions due to RRI of 30% from baseline emissions of 0.55 lb/MMBtu under full load operation, with less than 1 ppm of ammonia slip.

The objective of the testing at Sioux station was to determine whether similar performance could be obtained with RRI in a significantly larger unit. Sioux unit 1 has an opposed wall firing geometry with a total of 10 barrels on the front and rear walls. The recently installed OFA system was designed by REI to accommodate subsequent evaluation of RRI in this unit. The evaluation of RRI in Sioux Unit 1 consisted of: 1) CFD based modeling to design the RRI injection system and to evaluate expected performance, 2) Installation of temporary RRI hardware, 3) Field testing of RRI performance.

CFD BASED RRI DESIGN IN SIOUX UNIT 1

Pilot scale testing and fundamental chemical kinetic analyses have demonstrated the importance of the injection system design on RRI performance. Injection of the reagent into the wrong conditions can not only result in limited NO_x reductions, but can cause an overall increase in NO_x emissions. To evaluate the best locations for reagent injection associated with RRI, REI utilizes CFD modeling. Since 1995, REI has been working with utilities to evaluate various approaches for reducing NO_x emissions utilizing CFD. Working with CNCIG, REI developed a model of combustion within a cyclone fired furnace. This work has lead to the retrofit of the majority of the cyclone fired generating capacity with OFA. Subsequent work with this group led to the development of a CFD model description of the RRI process.

Utilizing this model, and working closely with AmerenUE, a conceptual RRI design for Sioux Unit 1 was developed. This design included a total of twenty aqueous urea injectors located on the front, rear and side walls of the unit, below the OFA ports. Model predictions of the 20 injector design suggested that NO_x emissions could be reduced by approximately 25% below baseline emissions of 0.41 lb/MMBtu (obtained utilizing only OFA), with no accompanying ammonia slip under full load operation. Through minor operational adjustment to the existing FGR flows in the unit, NO_x reductions up to 30% were predicted with less than 1-ppm ammonia slip. Simulations also showed that due to the stratified flow in the lower furnace, improper reagent injection could result in little to no reduction in NO_x emissions, and even a net increase in certain circumstances.

TEST RESULTS

Field testing of RRI in Sioux Unit 1 occurred in two phases during August 2001 and March 2002. The first phase test results were obtained shortly after installation of the OFA system in this unit. During that time, the full load NO_x emissions from the unit had been reduced from the baseline emissions prior to OFA installation of 1.25 lb/MMBtu to approximately 0.55 lb/MMBtu following the OFA installation. At best, RRI was shown to reduce NO_x emissions by an additional 15-20%, lowering NO_x emissions to approximately 0.44 lb/MMBtu. Continuous ammonia measurements showed less than 1 ppm ammonia slip during this round of testing. These results were in contrast to the CFD model results which suggested that at least 25% NO_x reductions were achievable with RRI. Comparison between the model evaluation and the tests, and the relatively high furnace NO_x emissions (0.55 lb/MMBtu) suggested that the unit was not sufficiently staged during the first phase of testing.

Subsequent testing during phase II confirmed these suspicions. Baseline NO_x emissions (without RRI) were approximately 0.4 lbs/MMBtu throughout the second phase of testing. Boiler air flow measurements and the lower baseline NO_x emissions both showed the lower furnace to be more deeply staged during this phase of testing. As a result, RRI alone was able to reproducibly reduce NO_x emissions by an additional 30%, lowering NO_x emissions to 0.25 lb/MMBtu. As was observed during the first phase of testing, no ammonia slip was observed. Short term testing at 80% of full load showed that the same performance was achievable under that condition.

CONCLUSIONS

The second full scale demonstration of the RRI process in cyclone fired boilers equipped with overfire air has been completed. In Ameren's Sioux unit 1, a 10 barrel, 500 MW opposed wall fired unit, RRI alone was shown to consistently reduce NO_x emissions by 30% from baseline levels of 0.4 lb/MMBtu with no accompanying ammonia slip. These results are in excellent agreement with previously completed CFD model predictions of this process in Sioux unit 1. The test results, in agreement with model predictions showed that sufficient air staging is required for RRI to be effective. Measured performance in Sioux unit 1 was similar to that previously achieved in Conectiv's B.L. England unit 1, a three barrel, 138 MW cyclone fired furnace. In both cases, the field testing confirmed the CFD model predictions and demonstrated the importance of accurate CFD modeling to a successful RRI design. The results of these demonstrations suggest that similar performance could be expected in a wide range of OFA-equipped cyclone boiler types over a wide range of sizes and firing configurations.

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